Background

Water quality standards in the U.S. consist of:
- criteria that define the environmental conditions that must be maintained to support the uses for estuarine and coastal waters in the Gulf of Mexico, and for any numerical (quantified) criteria to protect designated uses from effects of nutrients. This is largely due to the absence of adequate data that would quantitatively link biological conditions to nutrient concentrations. The Gulf of Mexico Action Plan, an organization founded in 1995, has identified the development of numerical nutrient criteria as a major step in reducing nutrient inputs to coastal ecosystems. Nutrient enrichment in estuaries and coastal waters can be quantified based on response variables that measure photosynthetic license and water clarity, long periods, and time responses measured values of chlorophyll a concentration, total attenuation of suspended solids, and water clarity are needed to establish reference conditions and to quantify response relationships.

Approach

NASA remote sensing data are used to produce long-term time series of ocean color observations from 1984 to present, using corrected satellite measurements from the MODIS (Moderate Resolution Imaging Spectroradiometer) sensors on the Aqua and Terra spacecraft and from the TM (Thematic Mapper) and ETM+ (Enhanced Thematic Mapper Plus) sensors on the Landsat 5 and Landsat 7 spacecraft, respectively. MODIS instruments have provided data with near-daily coverage since 2000, while Landsat TM/ETM+ data, although available only every 15 days, extend back to 1984. Recent improvements in Instrument calibration and data correction techniques enabled merging the time series of observations from MODIS and Landsat.

MODIS data are processed to retrieve inherent optical properties and water clarity parameters with spatial resolution of 250 m that enables measurements even for small estuaries. Landsat suspended solids, and water clarity are needed to establish reference conditions and to quantify response relationships.

MODIS Products

Three series of water quality parameters are created from the Level 3 MODIS data products obtained from the MODIS Atmosphere Data Processing System (MA-DPS) and Atmosphere Archive and Distribution System (MA-DADS). The Level 1b calibrated reflectance products are processed using the SeaDAS software (developed and maintained by the GSFC Ocean Biology Processing Group) to apply atmospheric correction (based on SWIR and NIR bands) and to retrieve inherent optical properties (IOPs) of coastal and estuarine waters. Based on quality flags generated for each pixel, water clarity parameters are not produced for pixels that are identified as (1) cloudy or (2) cloud shadow in MODIS and (3) acquired at high surface wind angles.

The following IOPs are retrieved using the Quasi-Analytical Algorithm and are used to produce the water clarity parameters using the formula shown above:
- Inherent optical properties:
  - total absorption coefficient at 443 nm, \( a_{443} \)
  - total backscattering coefficients at 488 nm and 555 nm, \( b_{488} \) and \( b_{555} \)
  - phytoplankton absorption coefficient at 555 nm, \( a_{555}^{bp} \)

Dissolved attenuation coefficient for the photosynthetically active radiation:
- \( a_{PAR}^{diss} \)

Chlorophyll concentration:
- \( a_{chlorophyll} \)

Satellite-based monitoring of coastal and estuarine waters is of great interest for the following reasons:
- \( \Phi_{PAR} \) is the photosynthetic active radiation

Landsat Products

After applying radiometric calibration, Landsat image products are gridded to planetary reflectance and aggregated to pixel size of 30 m by averaging 9-pixel areas. Similarly to the SeaDAS processing of MODIS data, Landsat atmospheric correction is based on an assumption of negligible water reflectances in the SWIR spectral bands (1.6 and 2.2 µm), which enables extraction of atmospheric path reflectances from image data in the SWIR bands. Separation of the atmospheric contribution into molecular (Rayleigh) and particulate (aerosol) scattering, and estimation of aerosol optical thickness from the SWIR bands to the visible and NIR bands, and estimation of diffuse atmospheric attenuation coefficients are accomplished by modeling atmospheric radiation transfer using the MODTRAN software developed by the U.S. Air Force Research Laboratory. MODTRAN calculates use the same or comparable meteorological data (pressure and humidity) and scene data as the SeaDAS processing. Land mask and cloud mask are derived for each image from the 1.5-µm SWIR band.

Currently, SWIR-based atmospheric correction of MODIS data in SeaDAS is based on the 1.3-µm and 2.2-µm bands because of problems with data quality for the 1.6-µm MODIS band on the Aqua satellite. A recent study has shown that for highly turbid coastal waters, the 1.5-µm band provides a more accurate atmospheric correction than the 1.3-µm band.

Conclusions

Results shown in Figure 1 and Table 2 are in agreement with the time series of remote sensing reflectance measurements Land and MODIS in the Mobile Bay estuary, despite differences between spectral responses of the instruments. These results validate the use of Landsat data products, aggregated to match the MODIS pixel size, to extend the high-resolution (250 m) MODIS time series of water quality parameters back to 1984.

Combining MODIS and Landsat data enables creation of long-term time series of water clarity parameters derived from remote sensing observations that will support development and implementation of water quality standards and development of land-use management policies for coastal and estuarine waters.